



# R.C.A. INSTITUTES. INC. *formerly* MARCONI INSTITUTE *Founded 1909*



## Technical Lesson 61

### COMMERCIAL TUBE TRANSMITTERS

Type E.T. 3628 Tube Transmitter. Vacuum tube transmitters are rapidly replacing spark and arc sets because of two reasons:

1. They are capable of covering much greater distances with less power.
2. They emit a sharper (less interfering) wave than either the spark or arc.

The E.T. 3628 is one of the standard transmitters now in use on many ships and in a few coastal stations. A vast amount of radio transmitting apparatus has been installed on ships since the birth of radio communication and while the advancement in radio has progressed, there was a limitation set, naturally, in the discard of older types to accommodate the more efficient newer types. Towards the relief of such an expensive change the Radio Corporation of America designed the E.T. 3628 tube set which utilizes much of the apparatus used in the old standard P-8 spark transmitter that we have just recently studied. The E.T. 3628 is often referred to as the "Converted P-8". In this lesson we show the changes made and if the student will study this assignment with the lesson on spark transmitters the instruction will be clear.

All connections to the motor-generator and automatic starter are the same as for the P-8 spark set. The method of Keying, (by breaking the primary circuit of the power transformer) is exactly the same as used with the P-8 installation. Power regulation by means of generator field and motor field rheostats is the same. The connections to the wattmeter and antenna ammeter are also the same as used with the P-8 spark set. Instructions and diagrams given in the lesson on spark transmitters should be followed so far as any of the above mentioned circuits are concerned.

The conversion of the P-8 spark transmitter is made by removing the following parts: The quenched gap panel, airduct, primary condenser rack, coupling shaft and scale, rotary gap disc and muffler, change-over switch and adjusting handle, and all upper contact studs on the wave-changer panel. Also the primary reactance is permanently cut out and the primary inductance (pancake coil) is removed and replaced with the drum wound helix type called the "tank inductance", as shown in the photograph, Figure 1.

The tube cradle holding the two UV-204-A's is then installed and protected by a panel screen as shown in Figure 2. The filament by-pass condensers are mounted on the rear of the panel in a position directly in back of the filament voltmeter as shown in Figure 3. A large board holding the choke coil and condenser assembly is put in the place formerly occupied by the spark condenser rack. On this board are the grid leak resistor of 4,000 ohms, grid r.f.

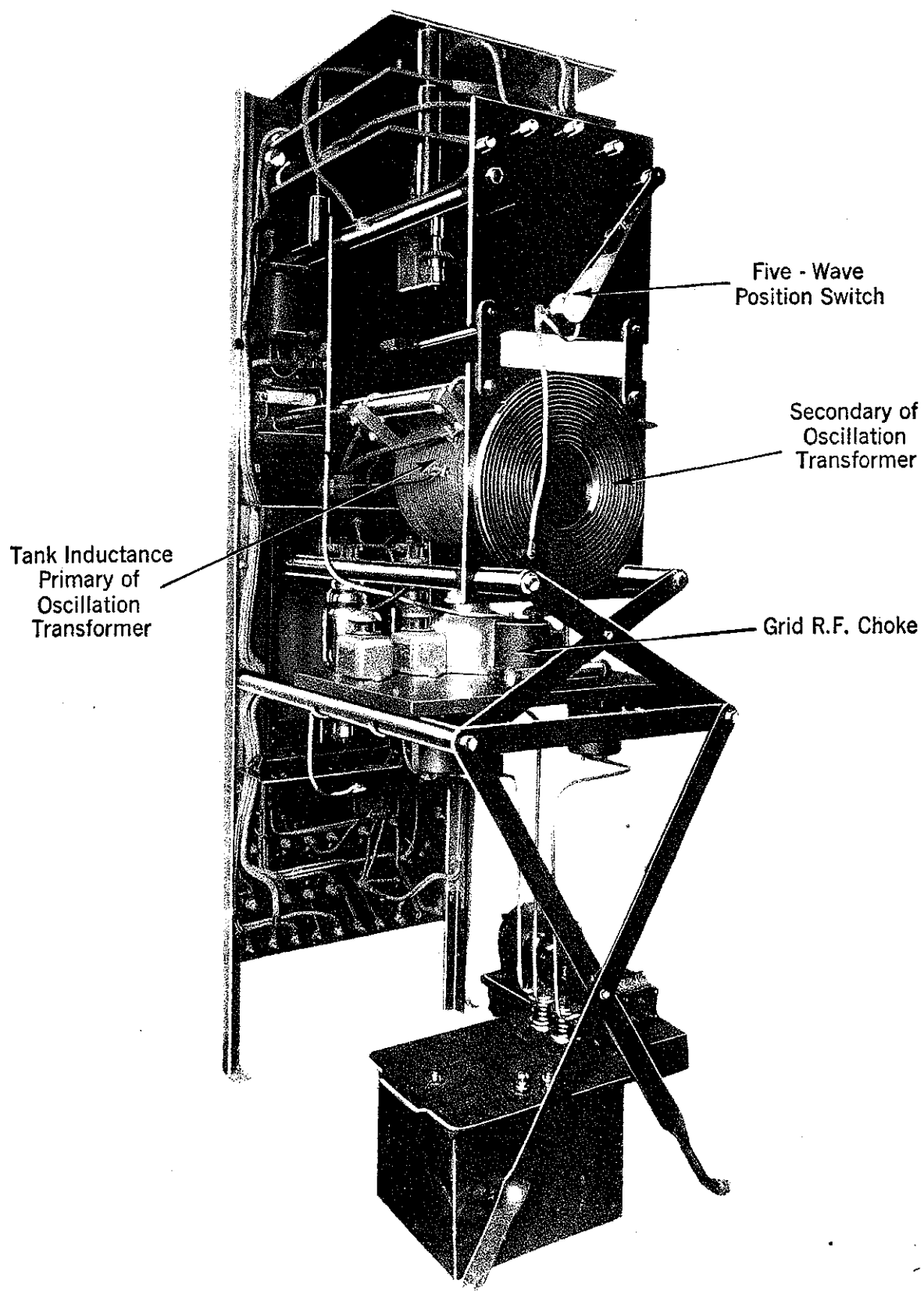


Figure 1

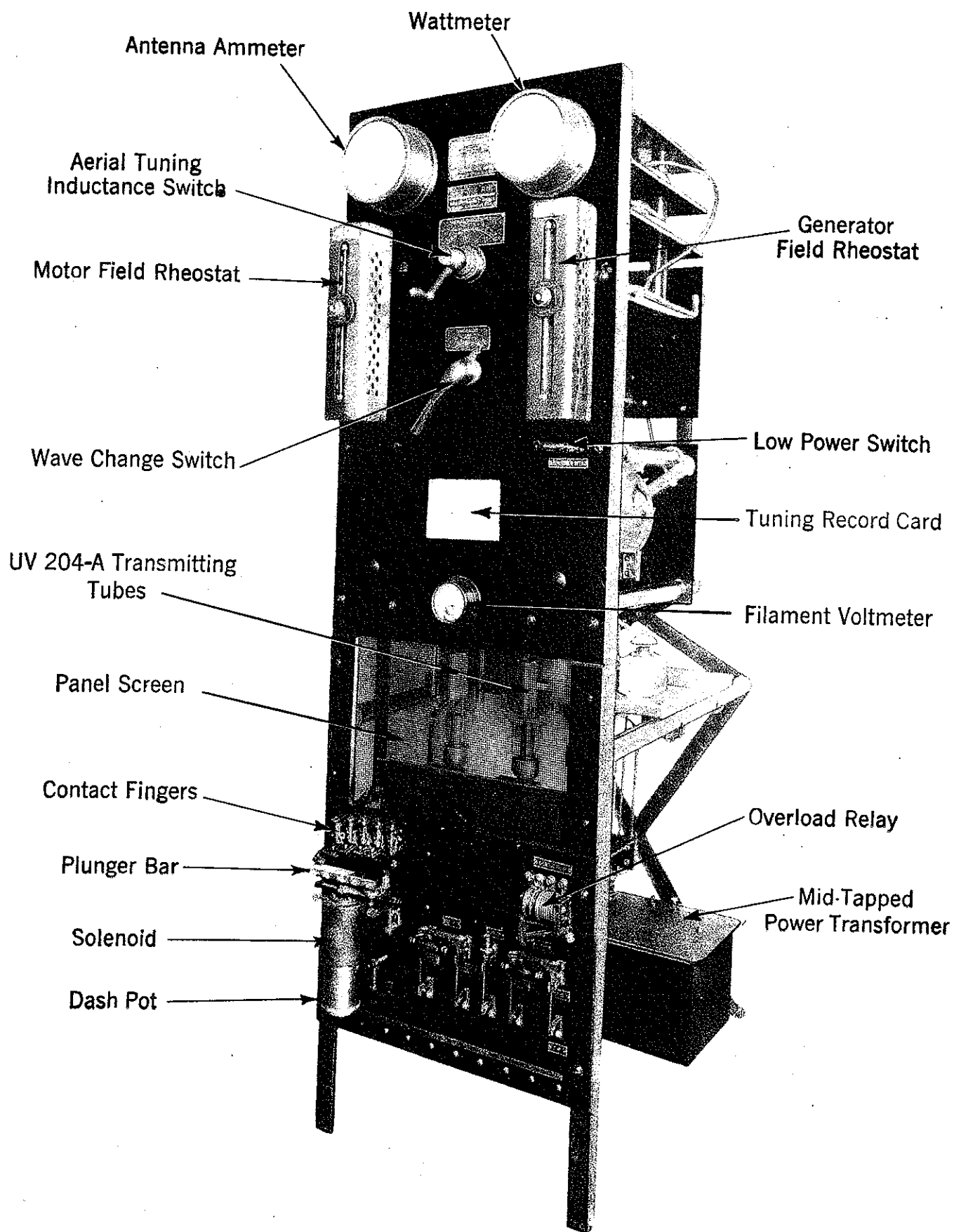


Figure 2

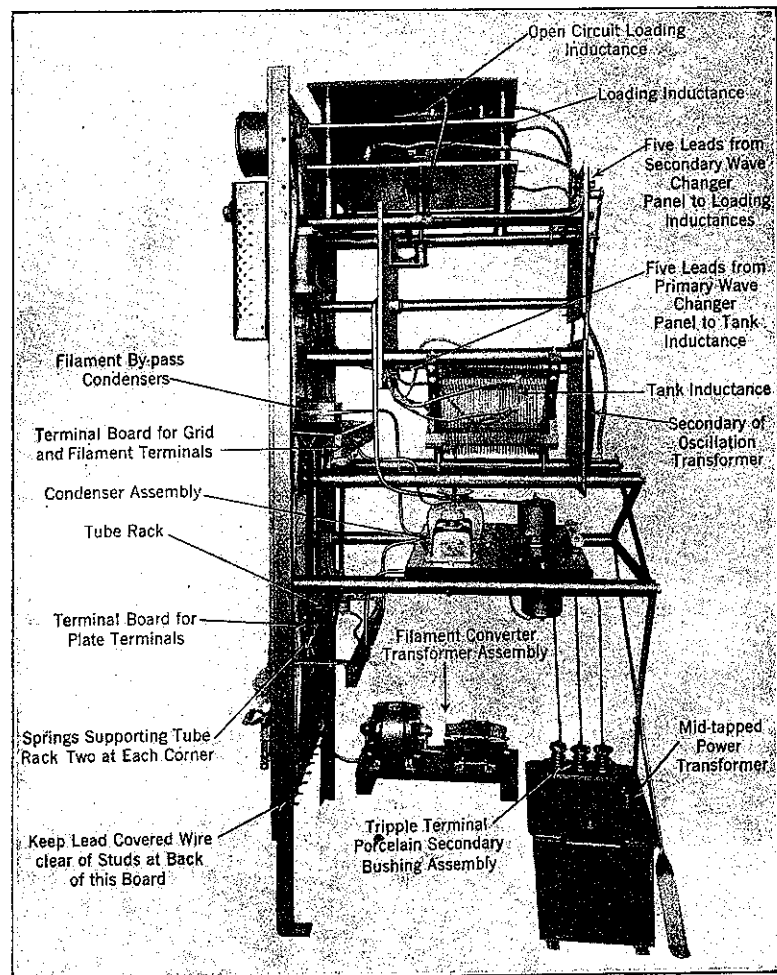


Figure 3

choke and the large plate excitation condenser on either side of which are mounted the two smaller plate blocking condensers. The two plate r.f. chokes are secured to the bottom of the board toward the rear.

The primary wave-changer panel is drilled for two additional contact studs and five flexible leads are connected, thus providing for a five-wave position holder. The circuit is the conventional Colpitt's oscillator type using flexible inductance leads making five wavelengths available as indicated in the schematic diagram of Figure 4.

The open oscillatory circuit of the E.T. 3628 is substantially the same as the P-8 except that the secondary inductance has only one variable tap which, after calibration, remains in a fixed position for all wavelengths. The spark transformer is replaced with a mid-tapped transformer. A filament voltmeter is mounted on the panel whereas the filament rheostat which controls the output of the a-c. rotary converter is usually placed on or near the operator's table. The mid-point of the filament transformer and mid-point of the plate transformer are joined with a heavy No. 12 gauge lead-covered wire which is connected to the ground.

Theory of Operation. Self-rectifying Tube Transmitter. The self-rectifying circuits may be divided into the following two classes:

1. Those employing one tube and utilizing only one-half of the a-c. cycle.
2. Those using both halves of the a-c. cycle by employing two tubes arranged symmetrically so that each tube operates alternately during the positive alternations of the a-c. cycle. The latter type is utilized in the E.T. 3628 described in subsequent paragraphs.

Tuning. The transmitting key is depressed and the power adjusted to  $\frac{1}{2}$ -kw. while watching the tubes for heating and sparking. If any one of the tube plates heat up badly, shut down the motor-generator and check over all connections, ascertaining if they are made to proper points and if they are clean and bright. This applies particularly to the wave-change switch arms. If trouble still persists, check through each unit of the transmitter. When clean, place the wave-changer switch on the first position and measure the wavelength with a wavemeter coupled to the tank inductance. Vary the clip on this coil until the desired wave is found. Then resonate the open circuit in the usual manner, using about two turns in the secondary inductance. The resonance point indicated by maximum antenna current is much sharper than is the case with a spark set and may be passed over unnoticed if the tuning is not done slowly and carefully.

The Number of Turns in the Secondary Inductance. Care must be taken not to include too many turns, resulting in too close coupling, in order to avoid the undesirable effect of "split" tuning. When this condition obtains radiation may be low and the wavelength will "swing" sharply from one value to another without warning or visual indication to the transmitting operator as the radiation is the same in both frequencies. The receiving operator, however, gets only the dots and dashes transmitted on the wavelength to which he is tuned and does not hear the others. There are two indications of split tuning to be watched for by the observer as outlined below. If the radiation increases evenly as the ATI (aerial tuning inductance) is brought slowly up to the resonance point by turning the handle and radiation decreases evenly as the ATI is moved past this point, then the set is radiating on one wave. If, however, radiation falls off suddenly and sharply as the critical point is passed, it is an indication that two waves are being emitted and that the coupling is too close. A change in coupling is obtained by altering the number of turns used on the secondary inductance by going over the ribbon wire inch by inch with the clip very carefully, until a suitable point is found. Coupling is not changed by varying the distance between the two inductances as in the case of the spark transmitter. Another method of detecting split tuning is to note the point on the ATI scale at which resonance is reached. Move the ATI slider along the wire perhaps two or three turns past this point. Then bring it back to resonance. If the second resonance point differs from the first, reduce coupling until they agree. Antenna current of 10 to 12 amperes may be expected with average conditions on  $\frac{1}{2}$ kw. power input. The power input must not be allowed to exceed  $\frac{1}{2}$ kw. The safety gaps on the transformer secondary terminals should have  $\frac{3}{16}$ " clearance. Make all calibration adjustments on low power,  $\frac{1}{4}$  to  $\frac{1}{2}$  kw.

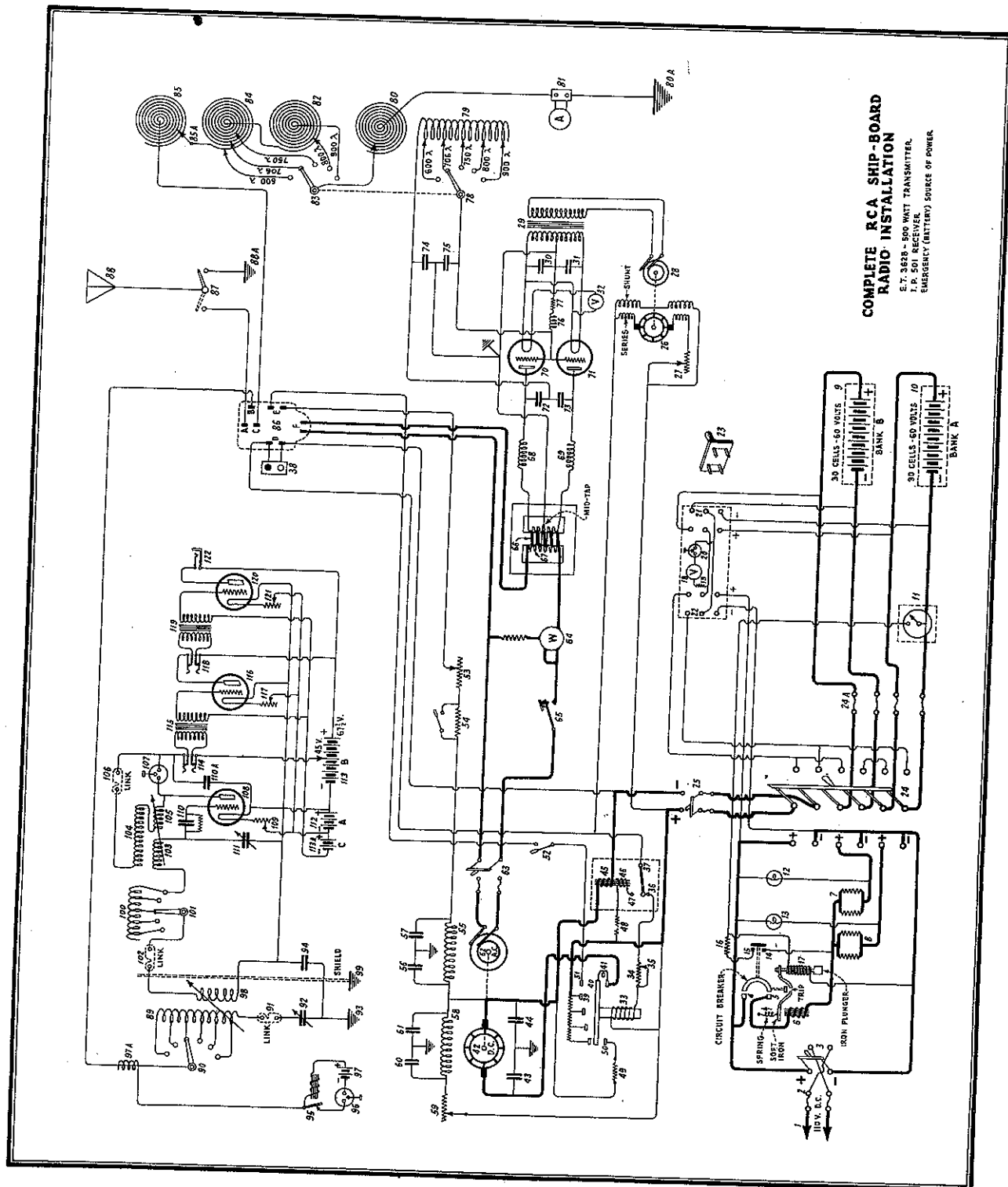


Figure 4

Suggestions. The three choke coils have similar characteristics and are interchangeable. If trouble develops in either plate choke coil remove the choke in the grid leak circuit and install it in place of the defective plate choke. The grid leak choke terminals may be jumped as this choke may be dispensed with for emergency operation. Emergency choke coils may be made up of two 400 turn honeycomb coils in series, or their equivalent.

If the antenna has not already been reinsulated with standard porcelain insulators, this should be done as the old hard rubber straps and rods are not satisfactory for CW. One porcelain insulator should be used in each halyard and rod insulators in the spreader guys. If a two-wire antenna is used, one porcelain insulator should be placed in each end of each wire, which will make it unnecessary to use any insulation in the bridles or guys.

Go over all connections periodically. It is of the utmost importance that the resistance of the antenna and ground system be reduced to a minimum. If the antenna wire is not in good condition it should be renewed and all connections made thoroughly tight. Instances of swinging signals from E.T. 3628 transmitters have been traced to faulty antenna construction, unnoticed on spark transmitters but showing up very badly with CW transmitters. The antenna should be secured as rigidly as possible to eliminate capacity changes and consequent swinging of signals. If the regular electrose deck insulator is not in first class condition, it should be replaced with a porcelain type deck insulator. The ground connection should be given special attention. It is suggested that at least three ground leads be run to different points in the hull or bulk-head, making sure that there is a direct metal connection between the bulk-head to which the ground lead is attached and the hull of the ship. Full advantage should be taken of all conduit pipe, heating system piping, and so on, utilizing these to supplement other ground points.

In any emergency due to failure of the motor-generator set or component parts the Converted P-8 transmitter can be operated from the 120 volt storage battery bank by placing the six-pole double throw switch, located in the charging panel, in the "discharge" position which is to the operator's right when facing the charging panel.

Communication could be carried on with this transmitter in the event of either one or both oscillator tubes becoming damaged and spares unobtainable. A damaged tube could be removed from the rack and the set operated with the remaining tube functioning as a half-wave oscillator. In case both tubes were found to be destroyed the circuit could be easily altered to take the form of a typical antenna spark discharge, where the antenna system is excited through direct connection to the outside terminals of the plate transformer secondary; the whole being connected across a small open gap. In order to accomplish this changeover, the vacuum tube circuit is completely removed from the plate transformer by disconnecting all three leads, the two attached to the outside ends and the one coming from the mid-tap. The safety gap remains connected across the secondary to serve in the capacity of a plain-antenna spark discharger. The antenna is attached to one end of the transformer and the ground to the opposite end. The mid-tap is left free. Each time the transformer voltage builds up sufficiently high to overcome the resistance of the gap a spark discharge takes place causing radio-frequency

oscillations to traverse the open radiative system. However, the distance between the electrodes of the safety gap must be adjusted so that a spark discharge will occur at the "peak" voltage of the transformer secondary output.

Placing the E.T. 3628 Into Operation. Before starting the 2-kw. motor-generator be sure that the motor and generator field rheostat controls on the panel are at lowest points and also adjust the filament rheostat resistance for minimum voltage. To start the set close the main line d-c. switch on the panel and direct current will then flow to the motor field windings. Next press the automatic starter button or throw the antenna change-over switch to the transmitting position. The direct current line is now closed through the starting solenoid, marked on the photograph in Figure 2, causing the plunger bar of the automatic starter to raise. The plunger bar moves up slowly, short-circuiting each one of the motor armature starting resistances in succession as it touches the finger contacts. This operation is necessary in order to prevent an excessive current flow through the armature when starting. The starting resistances compensate for the lack of sufficient counter e.m.f. until the armature attains full speed. The direct current line to the motor armature coil is closed, however, only when the bar touches the first finger and at this moment the armature will begin rotation. From this point on, the armature continues increasing in speed until the bar reaches its uppermost position, after which the speed remains constant. The motor speed may be changed by moving the slider of the field rheostat up or down, as the case may be. When the bar makes contact with the last finger on the right, current flows to the generator field through the low power resistor (shunted by a SPDT switch and the field rheostat). These latter devices regulate the a-c. output of the generator. The rotary converter used for filament excitation is set into operation when the antenna change-over switch ("send-receive" switch) is placed in transmitting position. Adjust the filament rheostat until the filament voltmeter reads 10 volts. Now close the a-c. main line switch and place the wave-changer switch on the desired wave. This should be followed by depressing the transmitting key and at the same time turn the aerial inductance handle which controls the sliding contact, until a maximum deflection is recorded on the radiation ammeter scale. This method for fine tuning permits the best conditions of resonance, between the closed and open oscillation circuits, to be obtained. It is advisable to repeat this adjustment when operating on any of the five wavelengths. Do not change the wavelengths while the key is depressed. When the maximum antenna current is obtained and with the wave-changer on the desired wave, the key may be operated for the transmission of messages. The set is stopped by pressing the push button "start-stop" switch.

As previously mentioned the power is regulated by the generator field rheostat and in no case should the wattmeter be permitted to read higher than  $1\frac{1}{2}$  kw. The single pole switch shunted across the low power resistor should be open when communication is established with nearby coastal stations in order to minimize interference.

The main line d-c. switch should be open when the set is not in operation because the motor fields are permanently connected across the line when this switch is closed. With the d-c. switch closed, current feeds to these coils continuously regardless of whether the motor generator set is running or idle.



## FUNCTION OF PARTS.

The antenna radio-frequency ammeter indicates maximum deflection when circuit resonance is established with the tank oscillatory circuit.

The loading inductances permit the antenna to be resonated with the closed circuit at the five wavelengths available.

The aerial tuning inductance is a continuously variable inductance having a sliding clip which can be moved by rotating the topmost handle on the front of the panel. The inductance can be increased or decreased inch by inch permitting a critical resonant adjustment to be obtained on all waves.

The primary inductance, called "tank inductance" or "plate coil", is used for obtaining the correct amount of inductance for a certain capacitance in the excitation condensers to promote the generation of continuous oscillations. Also, the tank inductance, being mutually related to the secondary inductance, functions to transfer part of its energy by electromagnetic induction to the open antenna circuit, thus setting the latter into excitation.

A plate excitation condenser of .002 mfd. capacity is connected in series with the grid excitation condenser and tank inductance forming the closed oscillatory circuit. The plate condenser couples the output circuit or plate to the input or grid.

The grid excitation condenser of .014 mfd. capacity supplies the grids of the oscillator tubes with a radio-frequency alternating voltage obtained from the radio oscillations flowing in the tank circuit. This is known as the "feed-back voltage". It is seen from the diagram that the voltage drop impressed between grid and filament of the tubes is obtained through the two leads connected across only a portion of the total primary capacitance, i.e., the portion represented by the grid excitation condenser. This is a conventional Colpitt's oscillator circuit. The total capacity of the tank circuit is represented by both the grid and plate excitation condensers in series. Tuning this circuit to any required frequency is accomplished by varying the flexible leads on the primary inductance for any of the wavelength positions as designated.

The plate blocking condensers, of .001 mfd. capacity each, prevent the plate d-c. voltage supplied by the plate transformer from being applied directly to the grids of the tubes. These condensers are intended not only to isolate the d-c. circuit from the oscillating a-c. circuit, but they must offer a low reactance to the high-frequency component of the plate current and thereby serve as a by-pass path for this oscillating energy from the plates to the tank circuit. The plate supply system or power transformer secondary would be short-circuited if these condensers break down. The plate current flows through the plate r.f. chokes and the transformer secondary.

The plate radio-frequency choke coils keep the high-frequency current from backing into the power transformer circuit which would result in severe losses of energy. In this way the maximum flow of radio energy is maintained

in the tank circuit.

It will be noticed that the radio-frequency chokes are not single-layer wound coils but have a special form of winding. This construction was found necessary in order to prevent trouble due to burned-out chokes. The burning currents were frequencies of some even multiple of the fundamental or operating frequency of the transmitter. Because of the special winding, the chokes possess a greater amount of inductance and less distributed capacitance than the ordinary single-layer wound coil. To damage these special type chokes would require frequencies other than those that might possibly be generated in the circuits in which they are contained.

A filament heating transformer steps down the a-c. voltage to about 13 volts, no load. The filament rheostat permits the adjustment of the filament voltage.

A filament a-c. rotary converter receives d-c. power from the 110 volt d-c. line and delivers alternating current at 60 cycles to the primary of the filament transformer.

The grid leak resistance of 4000 ohms, connected in common to the grids of both oscillators, maintains the correct negative bias for stable operation.

A grid r.f. choke prevents losses through the grid leak circuit, i.e., high-frequencies which flow from the grid excitation condenser. The largest amount of this energy fed back from the plate circuit is necessary for building up a maximum alternating voltage on the grids to promote the generation of continuous oscillations. Also the grid choke will prevent ultra high-frequency or parasitic oscillations from being generated. The frequency of such oscillations, if allowed to occur, is governed by the plate to grid capacity of the two tubes in series and the inductance of the connecting leads.

The filament by-pass condensers allow the radio-frequencies to flow between the filament and tank circuit without opposition. Without these condensers the only other path provided would be through the windings of the filament heating secondary. These windings naturally would offer a high inductive reactance due to their turns and the presence of the iron core.

The plate power transformer is of the closed core type, and receives a low voltage 500 cycle current from its secondary, the opposite ends of which are connected to the plates of the oscillator tubes. Each tube alternately receives a positive and a negative voltage during successive cycles. Only the tube receiving a positive voltage at any particular time is active in permitting the flow of plate current. The plate voltage continually changes in strength at the low frequency (500 cycles) causing the generated continuous oscillations to vary their amplitude in like manner. This is called "tone or modulated" C.W. An explanation and curves showing the characteristic wave form of a modulated C.W. signal are given in the lesson on "Vacuum Tubes used in Transmitting". The primary circuit of the plate power transformer includes the transmitting key, wattmeter, and a-c. generator.

The hand transmitting key closes the generator a-c. circuit and energizes the plate transformer which in turn supplies the plate potentials necessary to set the vacuum tube circuit into oscillation.

The circuits of the motor-generator, automatic starter, and type "I" antenna switch are similar to those described in the lesson on spark transmitters.

A five position wave-changer switch changes the wavelength of the closed oscillatory circuit or tank circuit simultaneously with the open radiative circuit; both contact arms are connected mechanically as indicated by the dotted line in the schematic diagram, Figure 4.

Tuning. Split-tuning Indications. Whenever calibration of the Converted P-8 is performed the power should be adjusted to about  $\frac{1}{2}$  kw. and the tubes constantly observed during the process for heating and sparking. A rough tuning adjustment is first taken by placing the wavechanger switch on the lowest wavelength position and, with a wavemeter held near the tank inductance, measure the wavelength. (Note: The theory of operation of a wavemeter is given at the end of this lesson). The wavemeter condenser should be moved very slowly in order not to pass the exact point of resonance. The tank inductance is provided with only one clip which should be varied until the desired wavelength is obtained. This procedure is to be followed by resonating the antenna circuit to the primary or tank circuit. The adjustment is to be considered satisfactory when a maximum reading is obtained on the antenna ammeter. When tuning the antenna circuit care must be taken not to include too many turns on the secondary coil. It will be found that about two turns gives a sufficient amount of inductance for the proper transfer of power, and yet will not result in too close coupling between the primary and secondary circuits, a condition that usually produces an effect called "split tuning". It is essential that a transmitter be cleared of such an undesirable condition, providing it exists, because the frequency of the emitted signal will "swing" sharply from one frequency to another. The operator at the distant receiving station could only intercept the signals upon the frequency to which his receiver circuit is tuned and the other frequency, when the signal swings, could not be heard.

In order to detect the presence of split tuning the following two tests should be employed. First, the transmitter is in correct adjustment (i.e., only one frequency or wave is being radiated) when the antenna ammeter reading increases steadily while the open circuit is brought to resonance by turning the handle on the front of the panel marked "aerial tuning inductance", and if after the resonance point is passed the ammeter reading is again seen to decrease steadily. On the other hand, it may be accepted that two frequencies or waves are being radiated (i.e. split tuning) if the ammeter reading drops suddenly after the critical point or highest reading is passed. It may be assumed that the split tuning effect is due to tight coupling and this trouble may be corrected by changing the coupling. This is accomplished by altering the amount of secondary inductance used by very carefully going over the ribbon wire inch by inch with the clip until a suitable point is found and not by varying the distance between the two coils, they being in fixed mechanical relation to each other. The person performing the calibration must not touch any wiring or clips when the transmitting circuit is active. Second, another test for determining split tuning is to mark the resonant point on the aerial inductance scale while the handle is turned in one direction, and after passing the resonant point by two or three turns of the handle, reverse the direction and return to

resonance and again mark the scale. If the two marks do not coincide the coupling should be reduced until they do.

After the calibration is completed on low power, the power can then be increased to normal and an antenna current of about 10 amperes is usually obtainable. In order to provide adequate protection to the transmitter apparatus the clearance between the safety gaps on the plate transformer secondary are to be set at 1/16th inch.

Practical Suggestions. The connections in the transmitter and power units should be gone over occasionally and at such times the antenna and ground system should also be inspected. While ordinary faults in an antenna system used with a spark transmitter do not lower the efficiency to any appreciable extent they do become troublesome with a C.W. transmitter. In order to maintain the resistance of the antenna at a minimum the ground lead should make a clean metal connection with the hull of the ship. Two or three ground leads are generally required and these may be easily traced to their actual locations whether they be made on the hull, bulk-head, conduit pipe or heating system piping.

The old hard rubber straps and rods which insulate the antenna are generally replaced with porcelain insulators whenever C.W. operation is to be employed. The porcelain insulators inserted in each end of the one or two wires forming the horizontal elevated portion of the antenna, those in each halyard, and the porcelain deck insulator ( if one is used in place of the regular electrose deck insulator) should all be carefully examined for cracks or chips in their surfaces which would allow the insulators to absorb moisture.

In the transmitter proper all of the three r.f. chokes have similar characteristics and are interchangeable. If trouble develops in either plate choke coil remove the choke in the grid leak circuit and install it in place of the defective plate choke. The grid leak choke terminals may be jumped as this choke can be dispensed with for emergency operation. Emergency choke coils may be made of two 400 turn honeycomb coils in series, or their equivalent.

Maintenance. The filament rotary converter should be kept oiled and commutators clean. All parts of the transmitter must be protected from water and spray and kept clean and dry at all times. The bakelite panel and rods and the treated maple boards used in the set should, in particular, be wiped off with a dry cloth every day. Should the transmitter accidentally get wet, it should not be started until it has been wiped off and the insulation and choke coils have become thoroughly dry. The bearings of the 2 kw. motor-generator should be kept oiled and the commutators clean and free of sparking.

Should it become necessary to change tubes, this should be done carefully to prevent breakage. Tubes taken from the set should be immediately placed in the containers from which spare tubes were removed.

Troubles and Remedies. The circuit used is very stable and can be relied upon to operate satisfactorily under all conditions where the apparatus is not defective, except two conditions, as follows:

1. The oscillations will not start when the key is closed if there is a poor connection in the tank circuit or an intermittent breaking down of the tank circuit insulation either to ground or in the condensers.
2. When the antenna coupling is too tight the maximum antenna current cannot be obtained as the tank circuit will shift frequency when approaching resonance of the antenna circuit.

When the antenna is small, or the resistance very low, it will be found that the maximum output may not load the tubes to their full rating and, under these circumstances, no attempt should be made to increase the loading by over-voltage or change in circuits other than careful tuning and use of proper value of coupling.

The coupling is varied by means of changing the number of turns in the secondary inductance instead of by varying the distance between the primary and secondary coil.

Signals from these transmitters may swing slightly in rough weather due to the rolling of the ship, changing the antenna capacity. The antenna should be pulled taut to minimize this as much as possible. However, should excessive swinging be complained of, it will probably be because the secondary circuit is too closely coupled to the primary. The coupling should be loosened by decreasing the number of turns used in the secondary of the oscillation transformer. Usually not more than two or three turns are required on this coil for proper coupling. Any change in the number of turns used in the secondary coil must be compensated for by a corresponding change in the aerial inductance to bring the set back into resonance.

Burned Out Filament Converter, Filament Transformer, or Filament Rheostat. Disconnect all of these units and connect filament terminals directly to a five-cell lead-acid storage battery which will supply approximately the right filament voltage. Leads formerly connected to the mid-tap of the filament transformer should be connected to the negative side of the storage battery. The regular filament rheostat cannot be used with a storage battery as it will not carry the heavy current flowing directly in the filament circuit. However, the voltage of a five-cell storage battery should be so close to normal that no regulation will be required.

Burned Out Grid Leak. The resistance of the grid leak used on this transmitter is 4000 ohms. Should the grid leak become burned out with no spare available, a suitable resistance could be made up from material available on board ship by using a piece of rubber hose about a foot long, filled with salt water and plugged at both ends with wires extending through the plugs at both ends and making contact with the salt water in the hose. A little experimenting with the length of hose to be used should result in obtaining the proper value of resistance for satisfactory operation. Any suitable resistance having a value between 2,000 and 10,000 ohms may be used.

Another method which may be utilized in case a suitable material may not be found on board is that of the ordinary lead pencil - sharpening both ends to get the necessary contact with the lead. It can be shortened if necessary

to approach the required resistance. This is, of course, an emergency measure.

Filament Converter Fails to Start. In some cases the filament converter may not start immediately when the circuit is closed if maximum resistance is cut in with the filament rheostat. In such cases the armature of the converter should be turned over immediately by hand.

Trouble in One Side of Circuit Which Cannot be Repaired at Sea Due to Lack of Material. Spare tubes, a spare plate choke, spare grid leak and spare transformer secondary sections should be aboard at all times. If these spares are available and the set is properly cared for it should be possible to keep it always operating at maximum efficiency. It should be borne in mind, however, that, if necessary, this set may be operated at reduced power with only one good tube, one good plate choke and one good plate transformer. Should there be available only one good tube, one good plate choke, one good plate blocking condenser, or only one-half of the secondary of the plate transformer, the defective part should be removed from the circuit and the lead to the plate transformer on that side disconnected. The set may then be operated at reduced power on one tube with about half the normal radiation. If only one tube is used, care should be exercised to reduce the filament voltage to normal.

In the event of irreparable damage, making it impossible to use even one side of the circuit, a "plain aerial" spark transmitter for emergency use only may be made by removing all connections from the three secondary terminals of the plate transformer and connecting the antenna to one outside secondary terminal of this transformer and the ground to the other outside secondary terminal. The safety gaps on the secondary terminals will then serve as a spark gap, as previously stated in this lesson. Necessary changes may be quickly made by disconnecting the flexible lead from the secondary of the oscillation transformer, lengthening this lead as much as necessary and connecting it to one side of the power transformer. The other side of the power transformer should then be connected to the piece of copper tubing leading from the secondary of the oscillation transformer to the thermo unit of the radiation ammeter. This will tune the circuit and permit of reading the radiation on the radiation ammeter. It is very improbable that it will ever be necessary to resort to the use of the plain aerial circuit and such circuit should never be used unless the vessel is in distress and the transmitter damaged so that it cannot be made to function normally.

NOTE: Porcelain, micalex, or glass antenna and deck insulators should be used with this type of transmitter. If other forms of insulation are used there is likely to be an excessive drop in radiation during wet weather.

The UV-204A tubes used in this transmitter are provided with an X-L or thoriated filament, the characteristics of which are low power consumption and high electron emission at low operating temperature. This low temperature very considerably increases the life of the tubes.

The UV-204A tube has a nominal power rating of 250 watts output. The current required for filament heating is 3.85 amperes per tube. The filament voltage must never exceed 11 volts. Satisfactory operation should be possible at all times with the filament voltage adjusted to between 9 and 10 volts.

In case of severe overload resulting in overheating of the tube, the electron emission may decrease and oscillations may not start when the key is closed. Unless the overload has liberated a large amount of gas, the activity of the filament may be restored by operating at rated filament voltage for 10 minutes or longer with the plate voltage off.

In the case of all tubes equipped with thoriated filaments, the end of the useful life of the tube is usually reached before the filament burns out. A tube may have lost its emission and be useless even though the filament lights and it is not otherwise defective. If a tube cannot be reactivated by the method described above within a reasonable length of time, it should be replaced by one of the spare tubes.

Wavemeter. The wavemeter is one of the most important measuring instruments in the radio field, and is used to calibrate a transmitter or receiving circuit to a definite frequency or wavelength, its principle of operation depending upon the phenomenon of resonance. Some wavemeters are designed to transmit a radio-frequency energy which can be detected in a receiver, and the receiver may be calibrated from the known frequency of the wavemeter. Transmitters radiate their own energy, and a wavemeter held in close inductive relation to the transmitter oscillation transformer will have the energy impressed upon its circuit.

A suitable meter will indicate, by a maximum current deflection of its needle, when the wavemeter circuit is adjusted to resonance. This is done, usually, by varying the capacity of the air condenser. The condenser scale is marked in divisions, either directly in wavelength, frequency, or in degrees. If the condenser scale divisions are marked in degrees, a graph or chart will accompany the meter. The curves on the graph are so drawn that for any degree of setting of the condenser the corresponding frequency, or wavelength in meters, may be read.

The wavemeter consists essentially of variable condenser with its dial calibrated, and an inductance, called an "exploring coil", previously calibrated from a known standard of inductance. The meter which indicates the maximum current in this oscillatory circuit, comprising inductance and capacity, must be so arranged that the meter movement will not in any way impede the radio-frequency currents that flow. Therefore, there are two standard types in use, as follows:

The first type is the hot-wire meter consisting of a straight wire along which the currents flow. Since the heat dissipation increases and decreases with and increase or decrease of current the wire will expand and contract, and a small spool or bobbin is turned by any change in length of the hot wire. The spool is connected to the needle and a movement is imparted to the latter, causing it to deflect across the scale. Usually the divisions on the scale do not indicate the actual current flow, but are arbitrary divisions for comparative reading. The divisions are not uniform in length, but become gradually greater as the current intensity increases. This follows the current square law of alternating currents.

The second type in common use is the thermo couple. The oscillatory circuit



is brought to a junction which is composed of two dissimilar metals, for example, bismuth and antimony, and current which flows across this junction will produce an e.m.f. much the same as though the junction were heated by a flame. A galvanometer connected to the junction will indicate the value of the current. This meter is constructed similar to a d-c. ammeter, in that its electromagnetic winding acts upon a permanent magnet to give movement to the needle. The radio-frequency currents only pass across the junction and not through the meter windings. The meter scale is generally calibrated in divisions from 0 to 100, each of equal length because the deflection depends upon the magnitude of the e.m.f. produced at the junction. The value of the direct current is directly proportional to the e.m.f.

Most wavemeters are supplied with several inductances or exploring coils, only one of which can be used at a time, to cover a definite band of frequencies. The different coils are designed so that the frequencies they cover overlap at the upper and lower limits in order to provide a continuous frequency range.

NOTE: Radio operators are not required to employ wavemeters in commercial radio service. Whenever necessary to calibrate (adjust or resonate) a transmitter the work is attended to by government radio inspectors and the inspectors of the radio operating company. The subject of wavemeters will be taken up in detail in the lesson on "Short-wave Transmitters".

#### MAIN DIAGRAM LEGEND - FIGURE 4

- |                                                       |                                                           |
|-------------------------------------------------------|-----------------------------------------------------------|
| 1. D.C. supply, ship's generator.                     | 24a. Fuses.                                               |
| 2. Fuses.                                             | 25. Transmitter panel D.C. supply switch.                 |
| 3. Polarity reversing switch.                         | 26. Filament rotary converter. (D.C. end).                |
| 4. Main circuit contact of underload circuit breaker. | 27. Filament rotary converter voltage regulator rheostat. |
| 5. Main circuit contact of underload circuit breaker. | 28. A.C. end of filament rotary converter.                |
| 6. Circuit breaker overload electro-magnet.           | 29. Filament lighting transformer.                        |
| 7. Charging resistors.                                | 30. Filament by-pass condenser (.5 mfd.)                  |
| 8. Charging resistors.                                | 31. Filament by-pass condenser (.5 mfd.)                  |
| 9. Bank of 30 lead-acid storage cells.                | 32. Filament voltmeter.                                   |
| 10. Bank of 30 lead-acid storage cells.               | 33. Automatic starter solenoid coil.                      |
| 11. Ampere-hour meter.                                | 34. Solenoid coil protective resistor.                    |
| 12. Trickle-charge lamp.                              | 35. Short-circuiting contacts for protective resistor.    |
| 13. Trickle-charge lamp.                              | 36. Solenoid contact of overload relay.                   |
| 14. Low-voltage release coil.                         | 37. Movable contact of overload relay.                    |
| 15. Low-voltage release coil.                         | 38. Starting button switch.                               |
| 16. Limiting resistor.                                | 39. Starting resistors and contact fingers.               |
| 17. Low-voltage release coil.                         | 40. Contact bar.                                          |
| 18. Voltmeter.                                        | 41. Flexible connection.                                  |
| 19. Voltage multiplier.                               | 42. Motor armature.                                       |
| 20. Voltmeter switch.                                 | 43. Protective condenser (1 mfd.).                        |
| 21. Voltmeter plug receptacle.                        | 44. Protective condenser (1 mfd.).                        |
| 22. Voltmeter plug receptacle.                        |                                                           |
| 23. Voltmeter plug.                                   |                                                           |
| 24. Six-pole charge-discharge switch.                 |                                                           |



45. Overload relay coil.
46. Holding coil.
47. Holding coil contact.
48. Holding coil limiting resistor.
49. Dynamic brake resistance.
50. Dynamic brake contact.
51. Generator field contact.
52. Generator field switch.
53. Generator field rheostat.
54. Low power resistor and switch.
55. Generator field.
56. Protective condenser (1 mfd.).
57. Protective condenser (1 mfd.).
58. Motor field.
59. Motor field rheostat.
60. Protective condenser (1 mfd.).
61. Protective condenser (1 mfd.).
62. A.C. generator armature.
63. A.C. output switch.
64. Wattmeter.
65. Hand key.
66. Primary of plate transformer.
67. Secondary of plate transformer.
68. Plate choke coil.
69. Plate choke coil.
70. U.V. 204-A radiotron.
71. U.V. 204-A radiotron.
72. Plate blocking condenser (.001 mfd.).
73. Plate blocking condenser (.001 mfd.).
74. Plate coupling condenser (.002 mfd.).
75. Grid coupling condenser (.014 mfd.).
76. Grid choke coil.
77. Grid bias resistor, 4000 ohms.
78. Wave changing switch ("tank" circuit).
79. Primary or "tank" circuit inductance of aerial transformer.
80. Secondary inductance of aerial transformer.
- 80a. Ground.
81. Aerial ammeter and thermo-couple
82. Aerial load coil.
83. Wave changing switch (secondary circuit).
84. Aerial load coil.
85. Aerial tuning inductance.
- 85a. Aerial tuning inductance switch.
86. Aerial change-over switch.
  - A. Aerial connection.
  - B. Receiver connection.
  - C. Transmitter connection
  - D. Motor starter contacts.
  - E. Generator field contacts.
  - F. Key contacts.
87. Lightning switch
88. Aerial.
- 88a. Aerial ground.
89. Primary winding of receiving transformer.
90. Primary inductance switch.
91. Long wave attachment link.
92. Primary series condenser (.0008-.0045 mfd.)
93. Ground connection
94. Grounding condenser.
95. Buzzer tester.
96. Buzzer push button switch.
97. Buzzer battery.
- 97a. Buzzer pick-up coil.
98. Coupling of secondary inductance.
99. Shield.
100. Secondary inductance.
101. Secondary inductance switch.
102. Long wave attachment link.
103. Coupling coil of secondary inductance.
104. Tickler coil.
105. Coupling coil of tickler inductance.
106. Long wave attachment link.
107. Oscillation test button switch.
108. Detector tube U.X. 201-A.
109. Filament rheostat.
110. Grid leak and condenser.
- 110a. Plate to filament by-pass condenser.
111. Secondary tuning condenser (.00006-.00032 mfd.).
112. "A" battery (filament).
113. "B" battery (plate).
- 113a. "C" battery (grid).
114. Detector jack.
115. First stage coupling transformer.
116. First stage amplifier tube U.X. 201-A.
117. Filament rheostat.
118. First stage amplifier jack.
119. Second stage coupling transformer.
120. Second stage amplifier tube U.X. 201-A.
121. Filament rheostat.
122. Second stage amplifier jack.

## OPERATION OF APPARATUS

The E.T. 3628 Transmitter. The transmitter may be operated from the ship's generator or, in an emergency, from the storage battery, by throwing the six-pole switch (24) to the left or right, respectively. When using the ship's generator the storage battery panel circuit breaker should be open, disconnecting the storage batteries.

When the D.C. supply switch (25) on the transmitter is closed current will flow through the motor field (58). When aerial switch (86) or the starting button (38) is closed current will flow through the starting solenoid (33), through the protective resistor (34), through the lower contact of overload relay (36), through contact bar (37), and back to the negative line. This will cause the contact bar (40) to move upward. As soon as the bar touches the first contact finger current will flow through the starting resistance (39), through the flexible connection (41), through the motor armature (42), through the overload coil (45), and to the negative side of the line. The motor will now start and, as the contact bar continues to rise, the motor speed will increase until the bar reaches the top contact at which time the motor will be running at maximum speed. At this point the protective resistance (34) is automatically cut in the circuit by the contact (35) which is operated mechanically. The bar now touches the generator field contact (51) and current flows through the generator field (55). The output of the generator is controlled by the rheostat (53). Low power is obtained by opening switch (54) which cuts in the series resistance. As a safety measure switch (52) is used to open the generator field while the motor generator is running and the transmitter is not being operated.

The input to the primary (66) of the power transformer is controlled by the hand key (65) and measured by the wattmeter (64). The secondary (67) of the power transformer is center tapped (mid-tapped) and is connected to the plates of the two U.V. 204-A tubes. Plate choke coils (68 and 69) prevent R.F. currents from flowing in the transformer. The condensers (72 and 73) prevent the low frequency supply current from flowing in the R.F. circuits. Condensers (74 and 75) couple the plate and grid circuits respectively, and with the tank inductance (79), constitute the oscillatory circuit. Coil (76) is a grid choke for preventing the flow of parasitic currents, i.e., ultra high frequencies.

Switch (78) changes the wavelength of the tank circuit. It is mechanically connected to the secondary switch (83) thereby permitting the inductance of both circuits to be changed at the same time. The inductance of the secondary coil (80) remains fixed after the transmitter is tuned and it should not be changed. The thermo-coupled ammeter (81) measures the aerial current. Coils (82 and 84) are aerial load coils. Coil (85) is the aerial tuning inductance. The aerial change-over switch (86) transfers the aerial from the transmitting to the receiving position and vice-versa. The lightning switch (87) should be grounded when the operator is not on duty.

The filaments of the U.V. 204-A radiotrons (70 and 71) receive their current supply from the step-down filament transformer (29). The condensers (30 and 31) by-pass R.F. current around the transformer. The meter (32) measures

the filament voltage. The filament transformer is supplied from a small 100 watt rotary converter, the output of which is controlled by the rheostat (27).

The generator (62) output is increased by means of the field rheostat (53) until the safety spark gaps on the tank circuit condensers begin to spark over. The voltage is then decreased to a point just short of where sparking occurs; the wattmeter (64) should read about 1.5 k.w., the foregoing adjustment is for maximum outputs; lower outputs may be obtained by adjusting the generator field rheostat (53).

The key (65) should not be pressed while changing wavelengths in order to avoid arcing at the switch contacts.

To stop the transmitter the aerial change-over switch (86) is thrown to the receiving position. This not only shifts the aerial from the transmitter to the receiver but opens the key, generator field and starter circuits as well, eliminating the possibility of accident due to live circuits.

The I.P. 501 Receiver. When the aerial switch (86) is thrown in the receiving position received signal energy will flow from contact (B) to the primary inductance switch (90), thence through inductance (89) through the antenna series condenser (92), and to ground (93). The variable coil (98), a part of the secondary inductance, is employed to provide coupling between the primary and secondary circuits. Condenser (94) is used to ground the filament side of the secondary. When the primary and secondary are in resonance current will flow through the main secondary coil (100), the inductance of which is adjustable by means of switch (101). The purpose of condenser (111) is to tune the secondary. Coil (103) is a part of the secondary and is used to couple the tickler coil (105). Coil (104) is the main tickler coil.

The grounded shield (99) prevents undesirable induction between the primary and secondary circuits. When the oscillation test button (107) is closed the tickler coil is short circuited; this enables the operator to ascertain if the circuit is in a state of oscillation. A click indicates that the circuit is oscillating.

The remainder of the receiving circuit consists chiefly of a standard two stage audio amplifier with jacks (114-118-122) in each stage, and individual filament rheostats (109-117-121). Either the detector, first stage, or two stages, may be used for reception of signals. A crystal detector may be employed by connecting it to binding posts on the panel provided for that purpose, (not shown in the diagram). To aid in adjusting the crystal detector, and to test the set in general, the buzzer circuit (95-96-97) has been provided. It is inductively coupled to the aerial by the pick-up coil (97A).

In operating the I.P. 501 receiver the filament rheostats should be turned on, and the small "send-receive" switch on the receiver panel placed in the "receive" position. The coupling should be tightened, maximum primary condenser capacity used, and minimum secondary condenser capacity and minimum tickler coupling employed. These adjustments place the receiver in the "listen in" or "stand by" position.

When tuning for spark signals or I.C.W. the primary and secondary inductance switches are turned until the desired signal is heard, and both inductance and capacity are adjusted for maximum signal strength. The coupling between the primary and secondary should be loosened as much as possible. When tuning for C.W. signals the tickler knob should be tuned until the circuit is oscillating. The links 91, 102 and 106 are provided so that extra inductances may be used for long waves ( a long wave attachment is usually provided for use with this receiver ).

Storage Battery Charging Panel. To charge the batteries switch (3) is closed and the six-pole switch (24) is thrown to the left. The circuit breaker is now closed with the left hand and, at the same time, the iron plunger (17) is pushed up with the right hand to release the trip. Current will flow from the positive side of the line through contacts (4 and 5), through the under-load coil (6), simultaneously through the two battery banks (9 and 10), through the ampere-hour meter (11), and back to the negative side of the line. If the supply voltage becomes too low when charging, the circuit breaker will trip thereby preventing the batteries from discharging. Current will also flow through the contacts (14 and 15) on the rear of the panel, through the limiting resistor (16), through the overload coil (17) and back to the negative line.

If the supply voltage becomes too high when charging, the circuit breaker will trip because the current flowing through coil (17) will be strong enough to pull the iron lever downward.

When the batteries become fully charged the black needle on the ampere-hour meter (11) will reach the vertical position thereby short circuiting coil (17), releasing the iron plunger, causing it to trip the circuit breaker. A small amount of current will then flow through the trickle charge lamps (12 and 13) keeping the battery on a very slow (trickle) charge, otherwise the batteries will slowly discharge. To discharge the battery the six-pole switch (24) is thrown to the right. This connects both banks (9 and 10) in series giving 120 volts.

#### EXAMINATION - LESSON 61

1. What could be done in an emergency if the E.T. 3628 transmitter became temporarily inoperative?
2. What causes swinging signals?
3. Why are plate radio-frequency choke coils used?
4. What are the advantages of vacuum tube transmitters as compared to other types?
5. What is meant by the term "split tuning"?
6. Where are the "ground" connections usually made on ship-board?
7. In this lesson there is a statement that reads, "The loading inductances permit the antenna to be resonated with the closed circuit at the five wavelengths available". What is meant by this statement?
8. (a) Of what is the closed oscillatory circuit composed? (b) What is a "tank inductance"? (c) How is the filament voltage obtained for the U.V. 204A tubes?
9. If the ship's generator should fail from what source of supply would the transmitter motor-generator receive it's input?
10. (a) Why is a grid r.f. choke coil used? (b) Why is a grid leak used?